IMPROVING WATER QUALITY THROUGH SOUND CONSERVATION PRACTICES

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INTRODUCTION

Water quality is a major environmental concern in the United States. The agricultural sector has been targeted as a major contributor of nonpoint source pollution to the nation's waters. In 1989, the U.S Department of Agriculture (USDA) launched a water quality program designed to enhance water quality by protecting ground and surface waters from potential contamination by agricultural chemicals and wastes, especially pesticides and nutrients. The program goal is to be achieved by accelerating the voluntary adoption of best management practices (BMPs) by farmers, ranchers, and foresters.

A major thrust of the USDA Water Quality Program is the implementation of demonstration field projects across a broad range of physiographic settings in the U.S. The overall purpose of the demonstration program is to show producers how they can modify their pesticide and nutrient inputs, conservation systems, tillage and other management practices to effectively reduce the potential movement of agri-chemicals and agri-waste into ground and surface waters. Adoption of practices is to be accelerated by transfer of innovative and appropriate technologies from the project area to other areas in the county, state, and nation.

Three major USDA agencies, namely, the Cooperative Extension Service (CES), Soil Conservation Service (SCS), and Agricultural Stabilization and Conservation Service (ASCS), carry out the projects in a collaborative effort. The three agencies are staffed at national, state, and local levels. Other agencies, both federal and state, are additional collaborators on many of the projects. Local steering committees representing all the participating agencies monitor, guide, and direct on-site project activities.

This paper describes the Herrings Marsh Run Watershed Project in Duplin County, North Carolina, USA. It presents some of the results after five years of BMP implementation and surface/ground water monitoring. Several new initiatives that have been generated as a result of project activities will be discussed briefly.

SETTING

The Herrings Marsh Run Watershed typifies much of the Atlantic Coastal Plain region of the southeastern United States. Soil parent materials are marine and fluvial sediments containing porous sands and clays. Most of the soils are sandy and well drained. The landscape is moderately dissected, consisting of gently undulating uplands and gentle valley slopes. Most of the project area is upland.

Two aquifer systems describe the ground water in the project area--the Surficial aquifer and the Cretaceous aquifer. The Surficial aquifer is the saturated portion of the upper layer of sediments, typically 7-17 meters thick. The Surficial aquifer is unconfined, i.e., its upper surface is the water table rather than a confining bed. Thus, it is sometimes called the water table aquifer. Many shallow wells tap the Surficial aquifer, which is particularly vulnerable to contamination.

The Cretaceous aquifer is a grouping of several of the oldest and deepest sedimentary deposits, which lie directly over the basement rock. The Cretaceous aquifer includes confined aquifers and its thickness is 130 meters or more. This allows for deep productive wells

Agriculture in the watershed is characteristic of Duplin County, which has the highest agricultural revenue of any county in North Carolina. Over three-fourths of this revenue is derived from poultry swine. Crop production is intensive in the watershed. Major agricultural crops are: Corn (350 ha); soybeans (200 ha); wheat (200 ha); tobacco (100 ha); cotton (100 ha); vegetables, e.g., cucumbers, sweet potatoes (150 ha).

The sandy soils, fluctuating water table, and intensive crop and livestock operations provide a setting conducive to surface and ground water contamination. Animal wastes from confined swine and poultry operations are potential sources of nitrogen phosphorus, and organic contaminants. Large amounts of mineral fertilizers in addition to animal manures are used for crop production. Pesticide use is extensive in the watershed, with about 50 different chemicals being applied.

BEST MANAGEMENT PRACTICES

Some of the accepted conservation practices in the watershed are: Conservation crop sequence; conservation tillage; crop residue management; cover crops; field borders; grassed waterways; terraces; row arrangement; and diversions. Agricultural producers are being encouraged to develop comprehensive resource management plans for their farms. Such plans include BMPs to reduce the potential for nutrients, pesticides, and sediment to degrade water quality. Improved nutrient management practices include soil sampling, crop tissue sampling, waste sampling, calibration of application equipment, and split applications of fertilizers, especially nitrogen. Nutrient management plans have been developed for about 80% of the cropland in the watershed. Improved pesticide management practices include integrated pest management and pesticide handling practices. Pest management plans have been developed for about 60% of the cropland.

Other BMPs include animal mortality composting and improved waste storage facilities. Animal waste management plans have been developed for all of the swine producers in the watershed.

Producer surveys are being used to track land use and land treatment activities at field and watershed levels. Separate surveys for cropping and animal production systems are used. The cropping system survey is designed to be useful in making nutrient and pesticide recommendations. Soil mapping units and SCS leaching indices are recorded along with soil, tissue, and waste analysis results, application rates/methods of nutrients and pesticides, tillage practices, and seeding rates. Five-year crop and yield histories are also obtained, along with descriptions of BMPs employed.

The animal system survey tracks production rates, feed consumption, and waste generation for each enterprise. Details of the waste management systems are recorded. The BMPs employed and their costs are also recorded for each farm

WATER QUALITY MONITORING

Water quality monitoring data on streams obtained from four continuous sampling stations. Ground water data are obtained from about 100 monitoring wells and private water supply wells. Exact locations of monitoring points are confirmed using global positioning (GPS) technology. Locations of the four continuous monitoring stations for stream discharge and water quality data are shown in Figure 1 Site 1 is located at the watershed exit, Red Hill. Site 2 is located along a tributary downstream from intensive swine and poultry operations. Site 3, the background site with relatively few potential inputs upstream, is located along the main stream flowing through woodlands. Site 4 is located upstream from Site 1 and monitors the eastern portion of watershed

Monitoring at the four stream sampling sites is conducted by USDA-ARS. Sample collection has been continuous from October, 1990, for Sites 1-3. sampler was installed at Site 4 in August, 1991, and sampling has been continuous since. Water samples are collected hourly and combined into eight-hour composite samples. They are analyzed for nitrate-nitrogen, ammonium-nitrogen, total Kjeldahl nitrogen, ortho-phosphorus, and total phosphorus. Stream discharge is recorded by the U.S. Geological Survey (USGS)

Mean nitrate-nitrogen concentrations in the surface water leaving the watershed (Site 1) and in a tributary (Site 2) were two- and four-fold higher, respectively, than background concentrations (Site 3). Daily nitrate-nitrogen concentrations at Site 2 sometimes exceeded 10 mg/l during the first year of sampling. Over application of waste water to fields probably accounted for the elevated nitrate concentrations at this sampling station. Since July, 1991, the maximum nitrate concentration at Site 2 has been 8 mg/l. Over a four-year period, a gradual decrease in nitrate concentrations at both Site 1 and Site 2 has been observed.

Ammonium-nitrogen concentrations of water leaving the watershed (Site 1) and in the tributary (Site 2) were two- and seventeen-fold higher, respectively, than at the background site (Site 3) during the first two years of sampling. Ammonium-nitrogen concentrations at Sites 1 and 2 exceeded limits considered harmful to humans (0.5 mg/l and fish (2,5 mg/l) These high amounts of ammonium-nitrogen indicate that a significant discharge of animal waste into the waterway had occurred. Ammonium-nitrogen levels at Sites 1 and 2 have decreased sharply since February, 1993

Stream flow data from the USGS gaging stations were integrated with the stream monitoring data to calculate the mass loading of nitrate-nitrogen and ammonium-nitrogen. In 1991 and 1992, the mass nitrate-nitrogen leaving the watershed (Site 1) averaged about 30 kg/ha per day. The tributary (Site 2) received about 20 kg/ha per day from its sub-watershed. These levels have decreased slightly with time.

Biological monitoring is conducted annually at Site 2 by the North Carolina Division of Environmental Management (DEM). Benthic macroinvertebrates are collected using the DEM standardized quantitative collection techniques. Aquatic fauna are inventoried, with the primary output consisting of a species list with indications of relative abundance (rare, common, abundant) for each taxon. Unstressed streams have a diversity of species, while stressed streams have relatively few species. Water quality ratings are assigned based on the abundance and characteristics of the most intolerant invertebrate groups. Potential stream bioclassifications are Excellent, Good, Good/Fair, and Fair. Baseline biological monitoring data indicate a bioclassification of Fair at Site 2 Biological sampling at this site and two additional sites will be repeated annually.

Monitoring wells (Figure 1) are located to evaluate impacts of specific land use practices on shallow ground water quality. Plastic wells ranging in depth from 8 to 12 meters are monitored monthly for nitrate-nitrogen and selected pesticides. Current well sites include a swine waste irrigation field pasture field receiving turkey mortality compost cropped areas for which nutrient and pest management practices are being implemented, and the turkey mortality composter site.

Nitrate-nitrogen concentrations at six monitored sites are shown in Table 1. The high levels of nitrate at Farm B are likely due to continuous land application of swine wastewater since 1986. The spray field is inadequate to retain all the waste produced by the swine operation which has expanded since its origination. Elevated nitrate-nitrogen concentrations at Site F are possibly due to pre-existing contamination from the contiguous poultry houses.

The slightly elevated nitrate-nitrogen concentrations at Sites A and C are likely related to nonpoint sources of nitrogen. Sites D and E appear to have appropriate nutrient management since the nitrate-nitrogen concentrations are less than 10 mg/l

Ground water samples were collected from 92 monitoring wells in 1993 and 1994, and analyzed for alachlor, atrazine, and metolachlor. Ohmicron Immunoassay kits were used. Over 18 months of monitoring, the immunoassay tests showed that small amounts of the three pesticides were detected in a few wells. The detection frequency appears to follow a seasonal pattern with higher detections found from April to July.

Alachlor was the most frequently detected herbicide, occurring in about 14% of the samples. Most of the wells with detections had alachlor concentrations much less than the maximum contaminant level (MCL). Despite high usage of atrazine, only a small number of the wells (5%) had positive immunoassay detections. Metolachlor detections also were low (5%). Athough there is heavy use of herbicides(700-850 kg annually) in the watershed, current pest management BMPs used by local farmers and applicators appear to be satisfactory for maintaining acceptable ground water quality.

MODEL APPLICATION

Water quality monitoring is essential for tracking surface and ground water changes as a result of BMP implementation. However, those changes are often subtle and a long period of time is required before significant changes appear. Therefore, modeling is being undertaken to estimate the impacts of management practices on water quality and farm profitability.

EPIC model, or Erosion/Productivity Impact Calculator, is being used to simulate nitrate and pesticide leaching. The EPIC model was used to simulate the impact of seven cropping systems on nitrate leaching. Pesticide leaching was simulated for three crops. Two scenarios were developed for each combination of crop and material under study. A conventional scenario was used to simulate the impact of cropland field management consistent with common practice.

Preliminary results indicate that substantial reductions in nitrate movement can be achieved with application of the alternative management scenarios. Minor changes in pesticide concentration in the leachate were predicted using alternative management. The low predicted concentrations are consistent with the pesticide monitoring data reported earlier. It provides additional support for the conclusion that farmers in the watershed are using appropriate kinds and amounts of pesticides to maintain good water quality.

Computer models are being selected for their suitability in simulating environmental and economic conditions in the Atlantic Coastal Plain. Data sets are being assembled for calibration and validation of these models. Water quality models will be used to estimate pollutant loadings for pre-, during-, post-implementation conditions for BMP systems adopted by producers. The impacts of specific BMPs, including nutrient and pesticide management, will be evaluated initially at the "bottom-of-root-zone" and "edge-of-field" levels. Efforts will later be expanded to model impacts on shallow ground water and stream water quality.

Field data from soil cores and monitoring wells in the watershed will be used to select, calibrate, validate appropriate models. Field data and error analysis procedures will be used to establish model inputs and to improve loading estimates
derived from the models. Models calibrated in watershed will be tested for nearby watersheds using limited monitoring data to assess transferability throughout the Coastal Plain region

At the completion of the project, selected policy alternatives will be evaluated for their impacts on farm practices, net returns, and water quality

Policy alternatives include cost-sharing and other economic incentives to adopt BMPs, limits to the quantity of selected contaminants that may be applied to critical areas, and other policies appropriate for consideration

SUMMARY

A five-year water quality project was initiated in North Carolina, USA, in 1990 to demonstrate the effects of using sound agricultural Best Management Practices (BMPs) on water quality. The project is being carried out on a 2000 ha watershed, Herrings Marsh Run, which is representative of catchment areas in the Atlantic Coastal Plain region of the United States. An intensive and diverse agriculture involving crops, swine, and poultry is practiced in the watershed.

Planning and implementation of BMPs is taking place according to schedule. Nutrient management plans have been developed for about 80% of the cropland. Pest management plans have been developed for about 55% of the cropland. Over one-half of all plans have been implemented.

Stream monitoring shows decreasing amounts of nitrate- and ammonium-nitrogen in the surface waters of the watershed. Ground- water monitoring shows relatively high concentrations of nitrate in areas of intensive swine and poultry operations. Groundwater monitoring of pesticides reveals low levels of alachlor, atrazine, and metolachlor even though large amounts of these chemicals are used on crops. Both stream and groundwater monitoring will be continued for several years to detect and measure changes in water quality.

Predictive models are being developed to estimate nitrate and pesticide leaching to the bottom of the soil profile and to the edge of field. Economic models are also being used to develop scenarios for maximizing agricultural sustainability and profitability while maintaining excellent water quality.

Index words: Best management practices, BMPs, modeling, demonstration, monitoring, USDA, water quality

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FIGURE

Figure 1. Location of stream water samplers (and gaging stations) and ground water monitoring wells in Herrings Marsh Run Watershed.

Table 1. Mean nitrate-nitrogen concentrations in groundwater monitoring wells located within the demonstration watershed.

Farm	Observation Duration, Months									
	1	2	3	4	5	6	7	8	9	10
	mg/L									
A	7	10	6	5	5	13	14	12	12	14
B	68	68	74	30	28	71	64	60	60	71
C	16	17	16	19						
D	5	6	5	5						
E	7	7	7	6						
F	12	7	18	-	9	10				

A = Continuous Corn, no waste
B = Grassland, swine waste
C = Row crop, no waste
D = Row crop, poultry compost
E = Row crop, poultry litter
F = Poultry compost site

Herrings Marsh Run Watershed